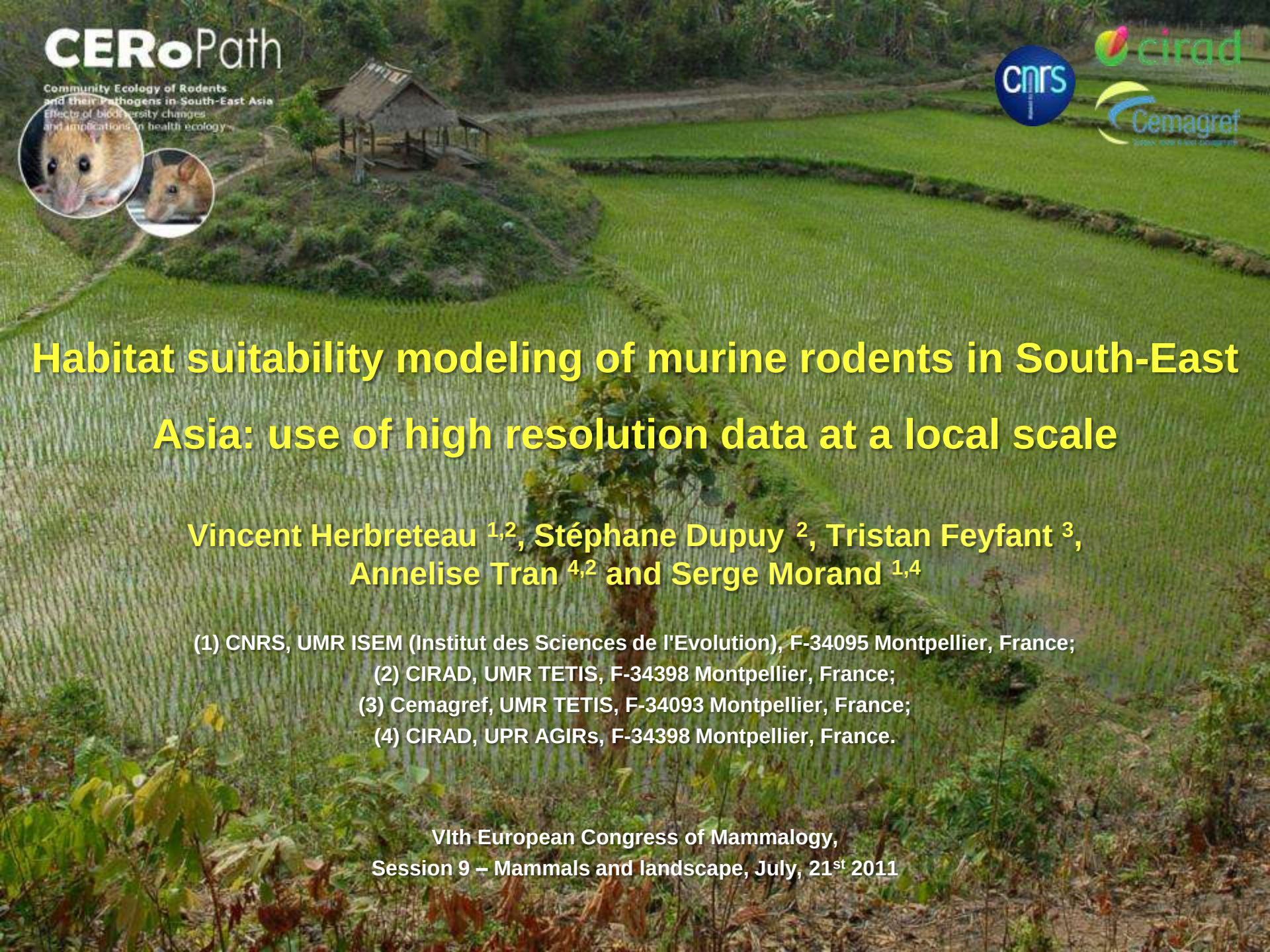

Habitat suitability modeling of murine rodents in South-East Asia: use of high resolution data at a local scale

Vincent Herbreteau [1,2], Stéphane Dupuy [2], Tristan Feyfant [3], Annelise Tran [4,2] and Serge Morand [1,4]

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(4) CIRAD, UPR AGIRs, F-34398 Montpellier, France.

VIth European Congress of Mammalogy,
Session 9 – Mammals and landscape, July, 21st 2011

CERoPath

Community Ecology of Rodents and their Pathogens in South-East Asia
Effects of biodiversity changes and implications in health ecology

Background

CERoPath project (ANR 07 BDIV 012) **:**

Community **E**cology of **Ro**dents and their **Path**ogens in South-East Asia

www.ceropath.org

→ aiming at understanding the implication of rodents in the transmission of diseases,

→ in a context of rapid environmental changes.

Photos: Herbreteau V.

Habitat suitability modeling of murine rodents in South-East Asia

- Understand the influence of spatial ecological heterogeneity on rodent communities.
- Estimate the environmental envelopes of these rodent species.
- Describe the distribution of rodent species in South-East Asia.

Introduction:

anything and everything in a "niche"

Can we pretend to model an ecological niche?

• Niche (or ecological niche) = a term describing the relational position of a species or population in its ecosystem

→ **We should distinguish between:**

- the **fundamental niche** = the total range of environmental conditions that are suitable for existence without the influence of interspecific competition or predation from other species;
- the **realized niche** = the part of the fundamental niche actually occupied by the species.

→ study of **"suitable habitats"** i.e. the ecological areas where a species can live.

Introduction:

anything and everything in a "niche"

Different terms used for niche / habitat modeling:

Ecological
Environmental **niche** modeling

Habitat suitability modeling

Resource selection/use modeling

Climate suitability modeling
response modeling

Bio-climate modeling

Species **distribution** modeling

Introduction:

anything and everything in a "niche"

Methods used in niche / habitat modeling:

- Relate the known occurrences of a given species to the environmental data.

Source: Open Modeller (http://openmodeller.sourceforge.net)

- Applications are usually based on the Grinnell's definition of ecological niches.

Introduction:

anything and everything in a "niche"

Methods used in niche / habitat modeling:

- Increasing number of algorithms and softwares developed:
  MaxEnt, ENFA, BIOMOD, Openmodeller, ModEco, GARP, BIOMAPPER, CANOCO, WinBUGS, OpenBUGS, DOMAIN, SPECIES, etc.

  together with statistical models: GLM, GAM, discriminant analysis, etc.

- Usually integrating global datasets (rasters, low spatial resolution)

→ Objectives of our study:
- model species accurately identified, described in the field and precisely located,
- integrate high resolution spatial data.

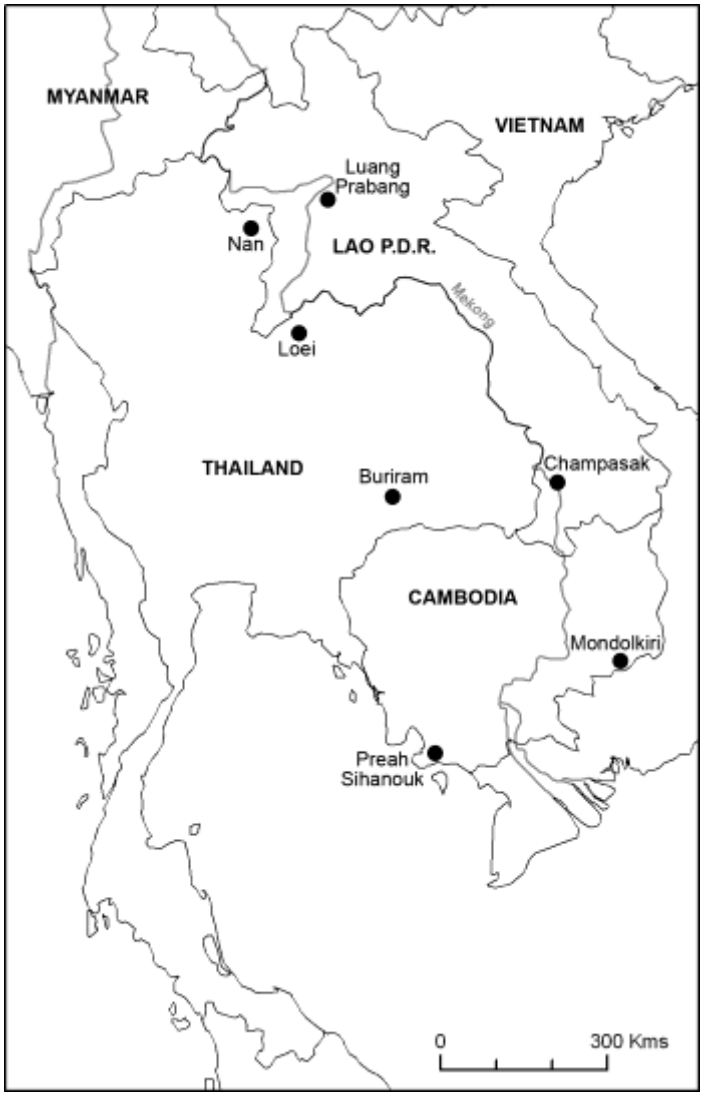
Material and Methods:

Rodent sampling

7 study sites in 3 South-East Asian countries (Cambodia, Lao PDR, Thailand):

- **Trapping in lines:**
  - 30 lines of 10 traps, left 4 nights:
    - 10 in forested areas,
    - 10 in dry fields,
    - 10 in wet ricefields.
    - → total of 1,200 night-traps
  - trapping during 2 season (wet / dry):
    - → 2,400 night-traps per site
    - → Total of 16,800 night-traps.

- **Complementary trappings:**
  - in villages,
  - in places with signs of rodent presence,
  - from hunters.

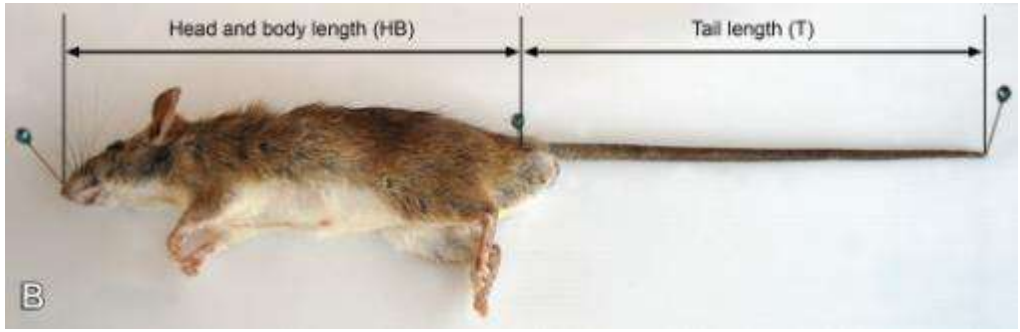


Material and Methods:

Rodent sampling

Rodent identification:

- Use of locally made live-traps.
- Field identification: external measurements and description.
- Genetic identification / CBGP-Montpellier

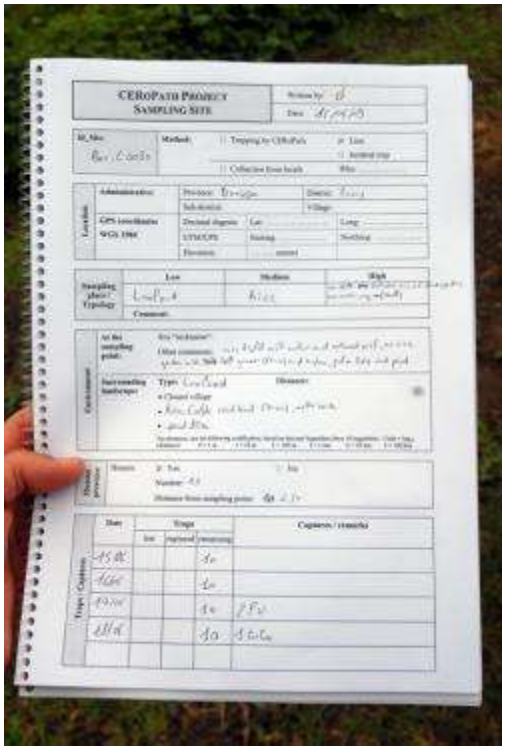


Material and Methods:

Rodent sampling

Environmental description:

- GPS locatisation of each sample.
- Description of the surrounding environment: landuse, distance to main landscape features, human presence, etc.
- Pictures taken around the trap:



0°

90°

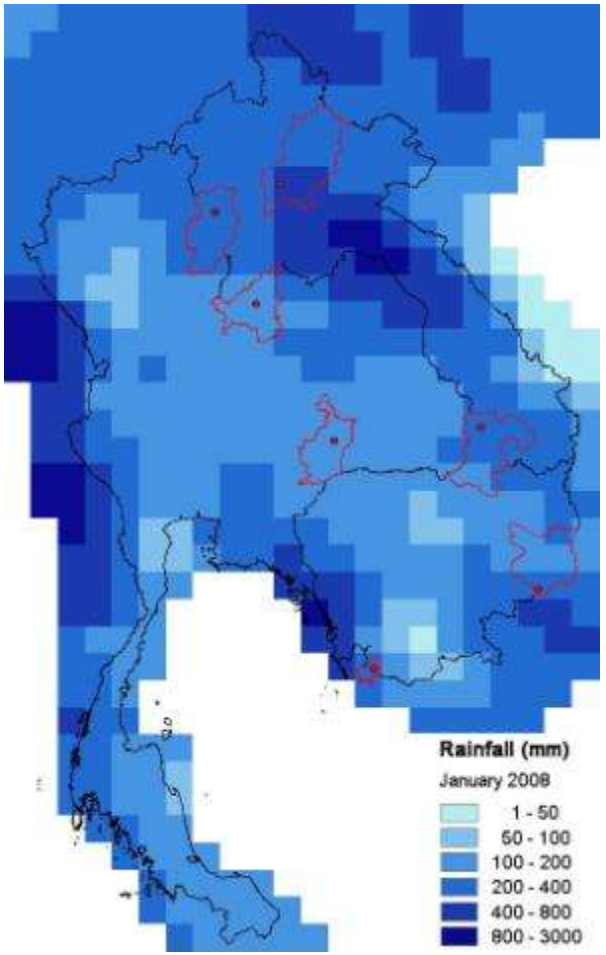
180°

270°

Material and Methods:

Global data

- **Climate data:**
  - **Global Precipitation Climatology Centre** (GPCC):
    - Provided by the Deutscher Wetterdienst.
    - Analyses the monthly precipitation on Earth's landsurface based on raingauge station data.
    - 0.5° (55.5 km) spatial resolution.
  - **WorldClim**:
    - compiled from different dataset and provided by: http://www.worldclim.org/.
    - 1/6° (approx. 18.5 km) spatial resolution.
    - 1950-2000 temperature and rainfall data.



Material and Methods:

Global data

- Climate data:
- **Topographic data:**
  - **Shuttle Radar Topography Mission** (SRTM):

    - Provided by USGS - NASA

    (http://srtm.usgs.gov/)

    - Digital Elevation Model with a 3 arc-second (approx. 90 meters) spatial resolution.

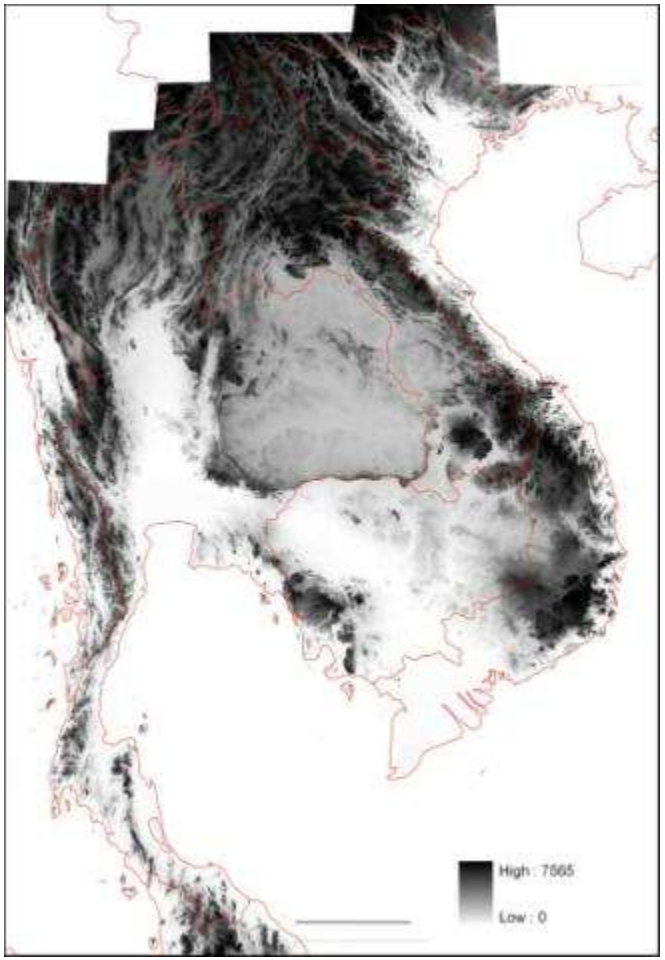
  - **ASTER Global Digital Elevation Model** (GDEM):

    - Provided by USGS - Japan's Ministry of Economy, Trade and Industry

    (http://www.ersdac.or.jp/GDEM/E/)

    - Digital Elevation Model with a 3 arc-second (approx. 30 meters) spatial resolution.

    - Serious artifacts.



Material and Methods:

Global data

- Climate data:
- Topographic data:
- **Land cover data**
  - **GlobCover 2.2**:

    - Provided by POSTEL (Pôle d'Observation des Surfaces Terrestres aux Echelles Larges) (http://medias.obsmip.fr/postel/)

    - Land cover map (2005-2006) derived from ENVISAT – MERIS satellite images (300 m spatial resolution).

  - **Global Land Cover Facility** (GLCF):

    - Provided by University of Maryland Dpt of Geography (http://www.landcover.org/)

    - Land cover map (1981-1994) derived from AVHRR satellite images (1 km spatial res.).

Material and Methods:

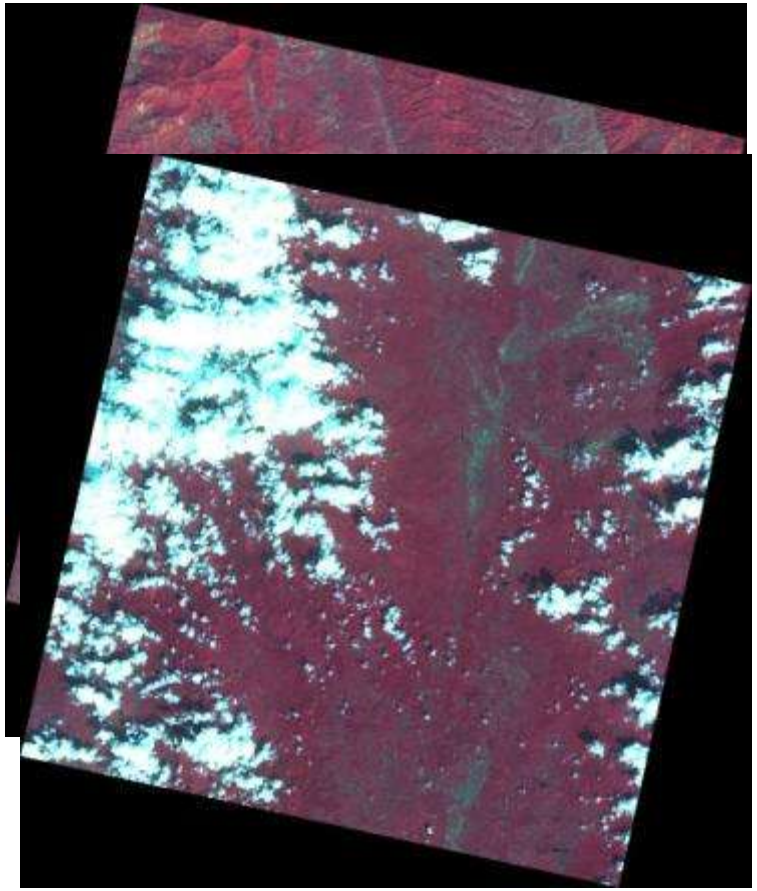
Local (high resolution) data

High resolution information can be gained through remote sensing:

- Acquisition of high resolution SPOT V images.

  SPOT data was provided via the ISIS program operated by the French Space Agency, CNES.

  → Difficulties to get high quality images from optical sensors in tropical areas



SPOT V image of Nan province, Northern Thailand

CERoPath

Material and Methods:

Local (high resolution) data

High resolution information can be gained through remote sensing:

- Acquisition of high resolution SPOT V images.

Study site	Date	Satellite / sensor	Image type / Spatial resolution
Cambodia - Mondolkiri	16/03/2008	SPOT 5 HRG 1	Pan / 5 . MS / 10
Cambodia - Veal Renh	19/12/2006	SPOT 5 HRG 1	Pan / 2,5 . MS / 10
	22/03/2007	SPOT 5 HRG 1	MS / 10
Lao PDR - Luang Prabang	31/10/2006	SPOT 5 HRG 2	Pan / 2,5 . MS / 10
	03/01/2007	SPOT 5 HRG 1	MS / 10
Lao PDR - Pakse	13/12/2007	SPOT 5 HRG 1	Pan / 2,5 . MS / 10
Thailand - Buriram	11/11/2006	SPOT 5 HRG 2	MS / 10
	17/01/2008	SPOT 5 HRG 2	Pan / 2,5 . MS / 10
Thailand - Loei	13/01/2007	SPOT 5 HRG 1	Pan / 2,5 . MS / 10
	19/04/2008	SPOT 5 HRG 2	MS / 10
Thailand - Nan	21/10/2006	SPOT 5 HRG 1	MS / 10
	12/01/2007	SPOT 5 HRG 1	Pan / 2,5 . MS / 10

Material and Methods:

Satellite images analysis

Satellite image pre-processing:

→ with ERDAS Imagine 2010®

- Radiometric calibrations (to make different images comparable):

  1- Conversion of digital numbers (recorded by sensors) to spectral radiance (i.e. total light emitted by the objects), according to the gain and bias of the sensor.

  2- Conversion of spectral radiance to exoatmospheric reflectance (because spectral radiance depends on the degree of illumination of the object, that varies with time of day, season, latitude).

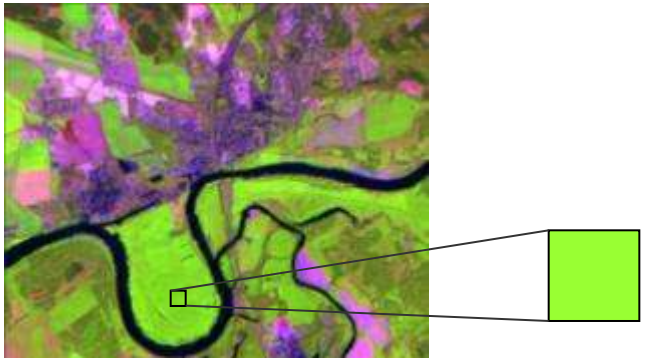
- Resampling the 10 m Multispectral images to 2.5 m resolution of the Panchromatic images.

Material and Methods:

Satellite images analysis

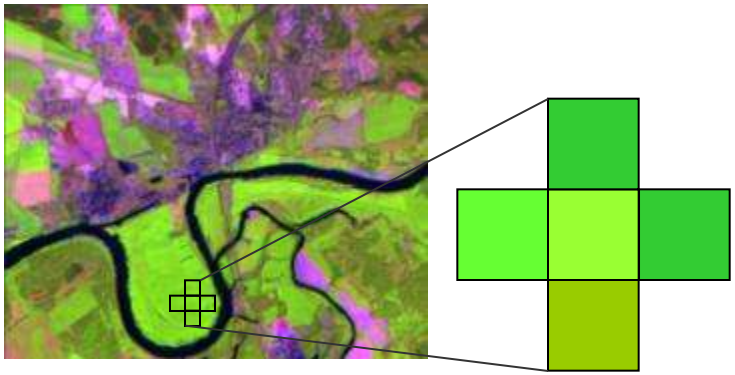
Different approaches of land-cover classification :

Pixel-based classifications



Each pixel is classified according to its spectral signature.

Contextual techniques for classification



Response and class of 2 spatially neighbouring pixels are highly related:

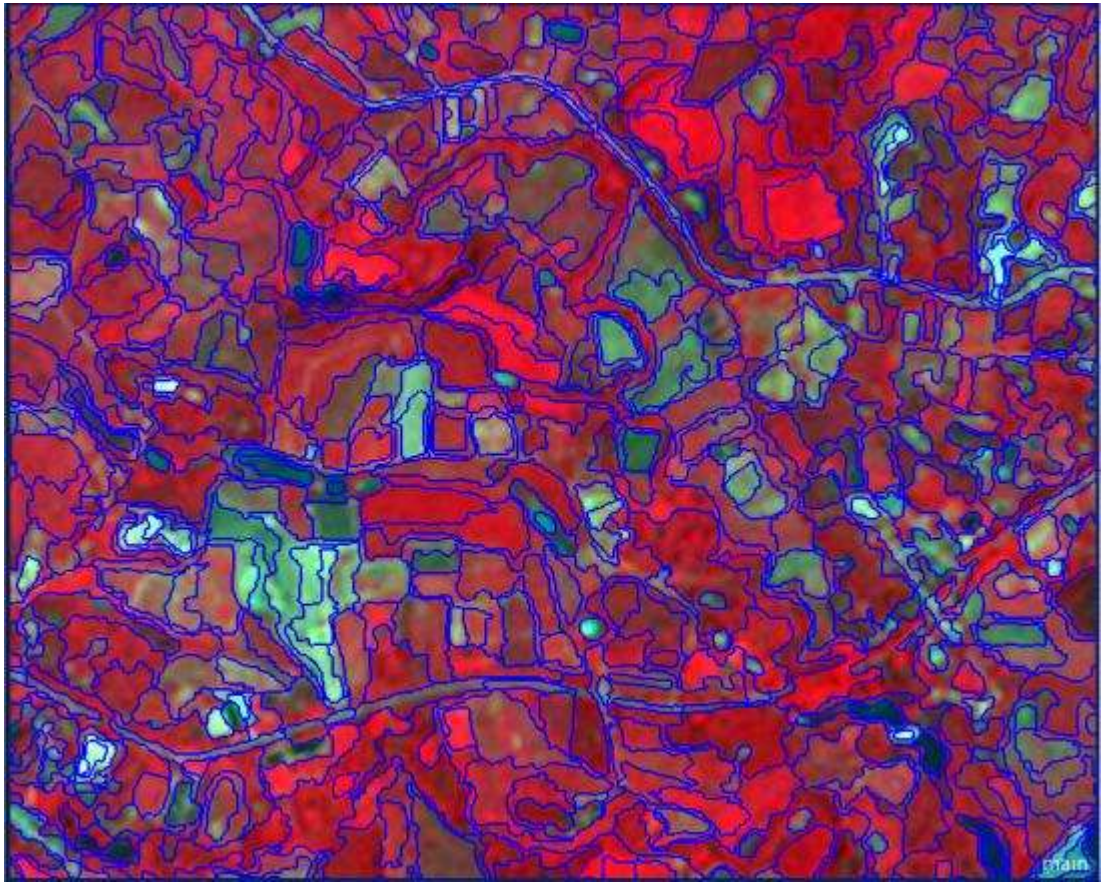
pixels are classified according to their context.

Material and Methods:

Satellite images analysis

Object-oriented classification : → with eCognition Developer 8®

1- Segmentation
(subdivision into homogeneous regions)



Classification of SPOT image from Loei province, Thailand

Material and Methods:

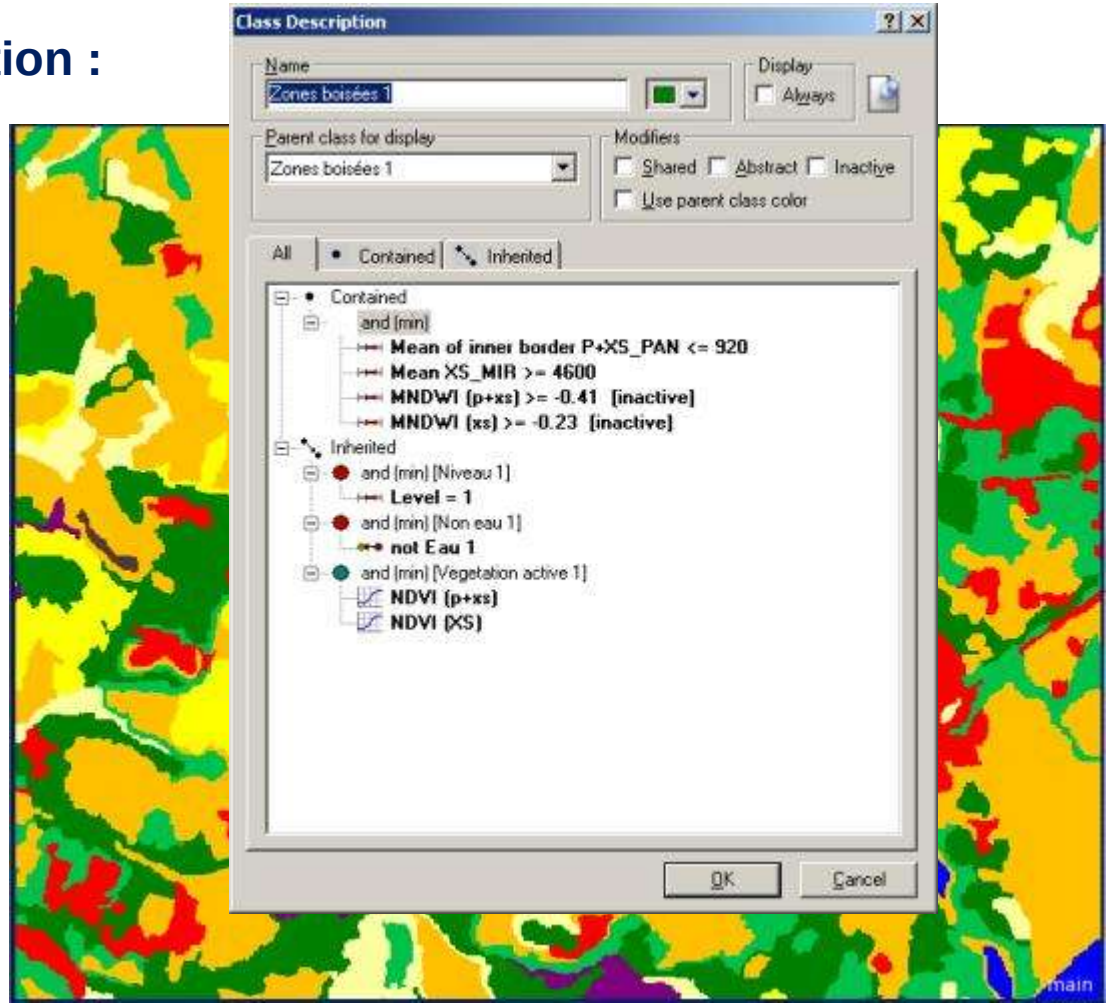
Satellite images analysis

Object-oriented classification :

1- Segmentation (subdivision into homogeneous regions)

2- Classification of each object depending on:

- **intrinsic features** (properties of object: shape, texture, reflectance)
- **topological features** (relationships to sub-/super-/neighboring objects)
- **context features** (semantic relationships between objects.



Classification of SPOT image from Loei province, Thailand

Material and Methods:

Satellite images analysis

Object-oriented classification :

→ **Necessity of field survey:**

- to identify the different categories of land cover / use,
- to validate the classifications.

→ with ESRI ArcPad®

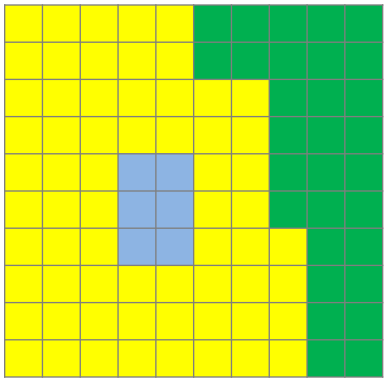
Material and Methods:

Landscape analysis

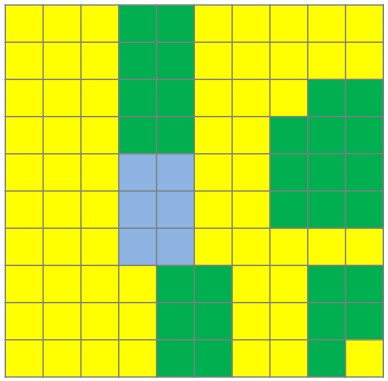
Increasing fragmentation

Occupation	Area (ha)
Forested area	30
Agricultural area	64
Water body	6

Continuous landscape



Fragmented landscape



Patch density (patches / ha)	0.03	0.08
Edge density (m / ha)	0.76	1.24

$$\text{Patch density} = \frac{\text{Number of patches}}{\text{Total area (ha)}}$$

$$\text{Edge density} = \frac{\text{Total edge (m)}}{\text{Total area (ha)}}$$

Material and Methods:

Landscape analysis

Increasing fragmentation

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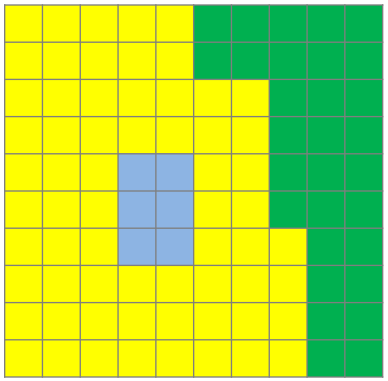
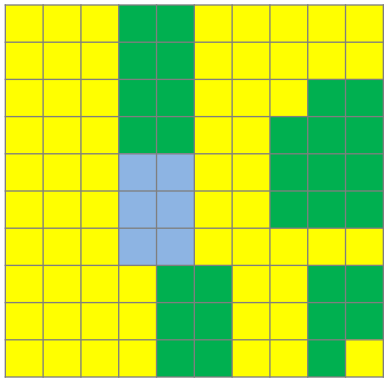
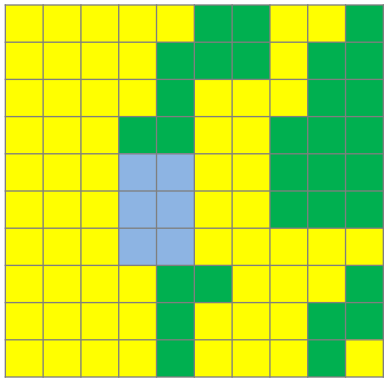
Continuous landscape



Fragmented landscape





Patch density (patches / ha)	0.03	0.08	0.08
Edge density (m / ha)	0.76	1.24	1.35

$$\text{Patch density} = \frac{\text{Number of patches}}{\text{Total area (ha)}}$$

$$\text{Edge density} = \frac{\text{Total edge (m)}}{\text{Total area (ha)}}$$

Material and Methods:

Landscape analysis

Increasing fragmentation

Occupation	Area (ha)
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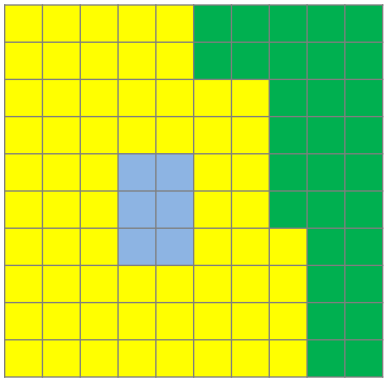
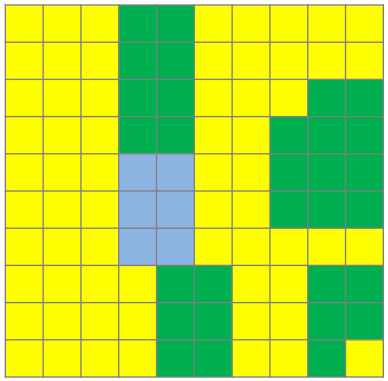
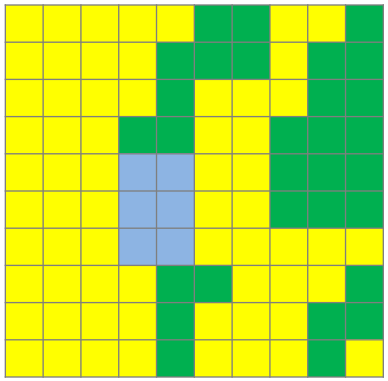
Agricultural area	64
Water body	6

Continuous landscape



Fragmented landscape





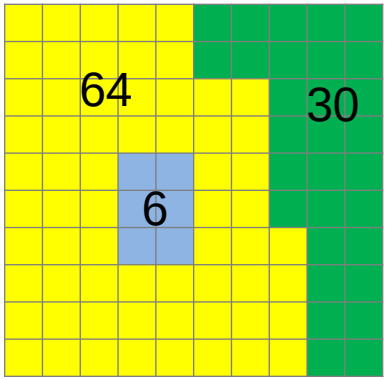
Patch density (patches / ha)	0.03	0.08	0.08
Edge density (m / ha)	0.76	1.24	1.35
Shannon Diversity Index	0.82	0.82	0.82

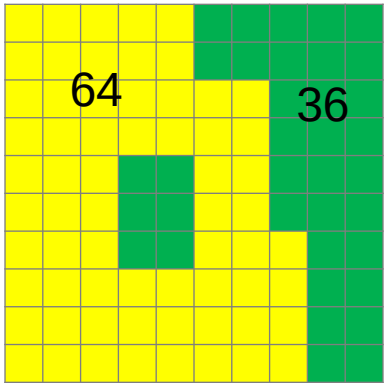
$$SHDI = -\sum_{i=1}^{m} (Pi * \ln Pi)$$

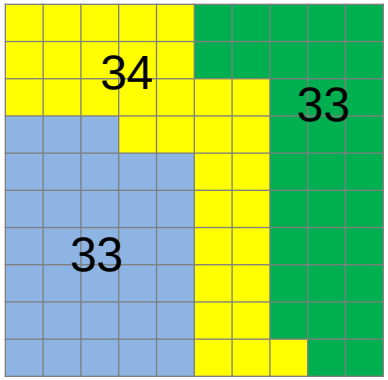
With P_i = proportion of area covered by land cover class I
wnd : m = number of patch types

Material and Methods:

Landscape analysis







Patch density (patches / ha)	0.03	0.03	0.03
Edge density (m / ha)	0.76	0.76	0.90
Shannon Diversity Index	0.82	0.65	1.10

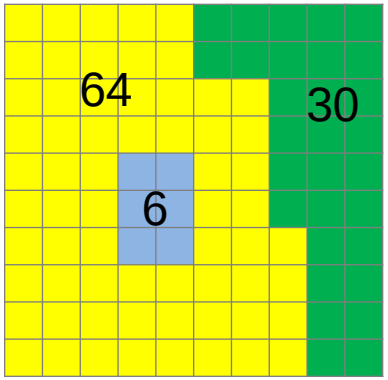
$$SHDI = -\sum_{i=1}^{m}(Pi * \ln Pi)$$

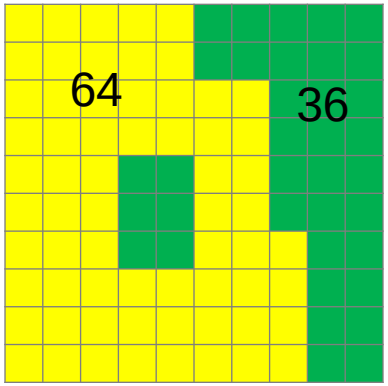
with: P_i = proportion of area covered by land cover class i
and: m = number of patch types

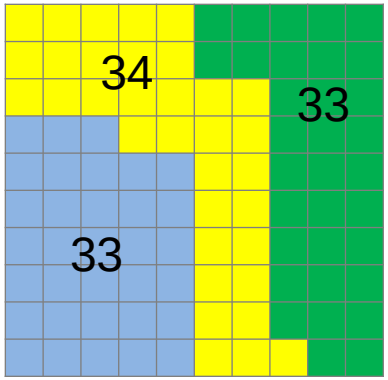
→ SHDI increases: - with the number of classes,
- as the proportion of each class becomes equal.

Material and Methods:

Landscape analysis





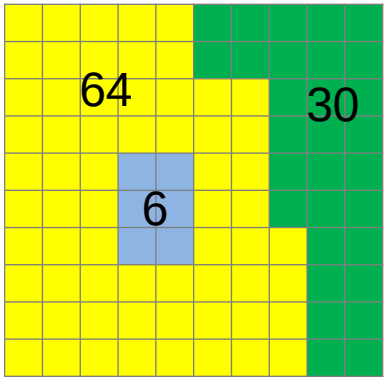


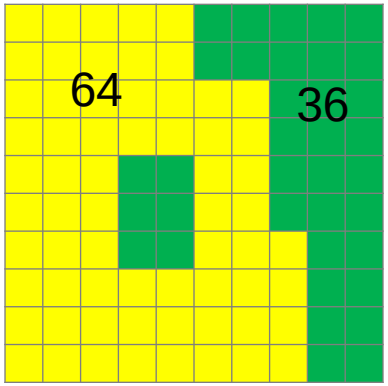
Patch density (patches / ha)	0.03	0.03	0.03
Edge density (m / ha)	0.76	0.76	0.90
Shannon Diversity Index	0.82	0.65	1.10
Shannon Evenness Index	0.74	0.94	1.00

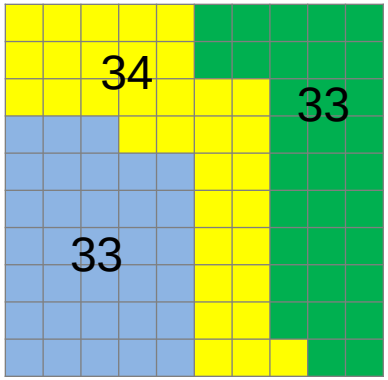
$$SHEI = \frac{SHDI}{\ln m} = \frac{-\sum_{i=1}^{m}(Pi * \ln Pi)}{\ln m} \qquad 0 \le SHEI \le 1$$

Material and Methods:

Landscape analysis







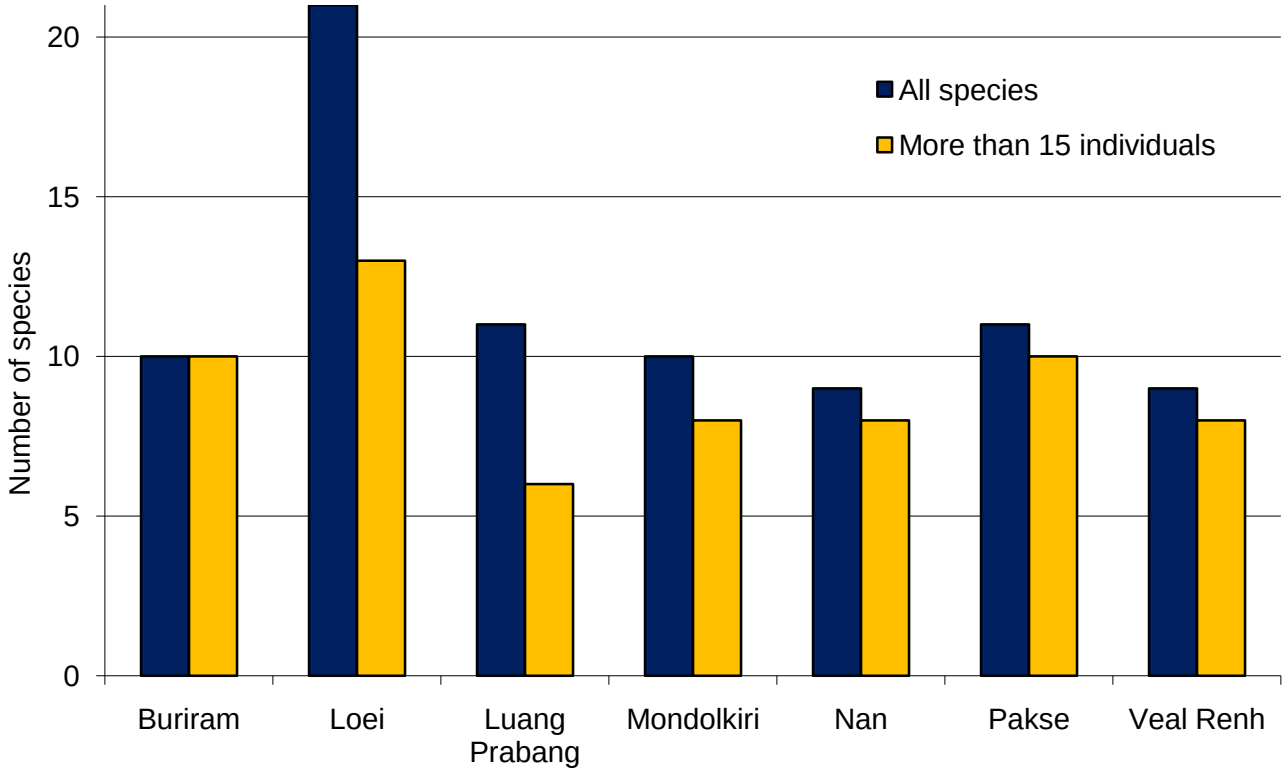
Patch density (patches / ha)	0.03	0.02	0.03
Edge density (m / ha)	0.76	0.76	0.90
Shannon Diversity Index	0.82	0.65	1.10
Shannon Evenness Index	0.74	0.94	1.00
Simpson Diversity Index	0.50	0.46	0.67

$$SIDI = 1 - \sum_{i=1}^{m} Pi^2 \qquad 0 \leq SHEI \leq 1$$

Results :

Rodent sampling

- Total of 1,534 murine rodents
- 24 species



Species richness per site

Results:

Ecological ranges

- Based on global data (DEM, climate):

Example: Range of elevation per species

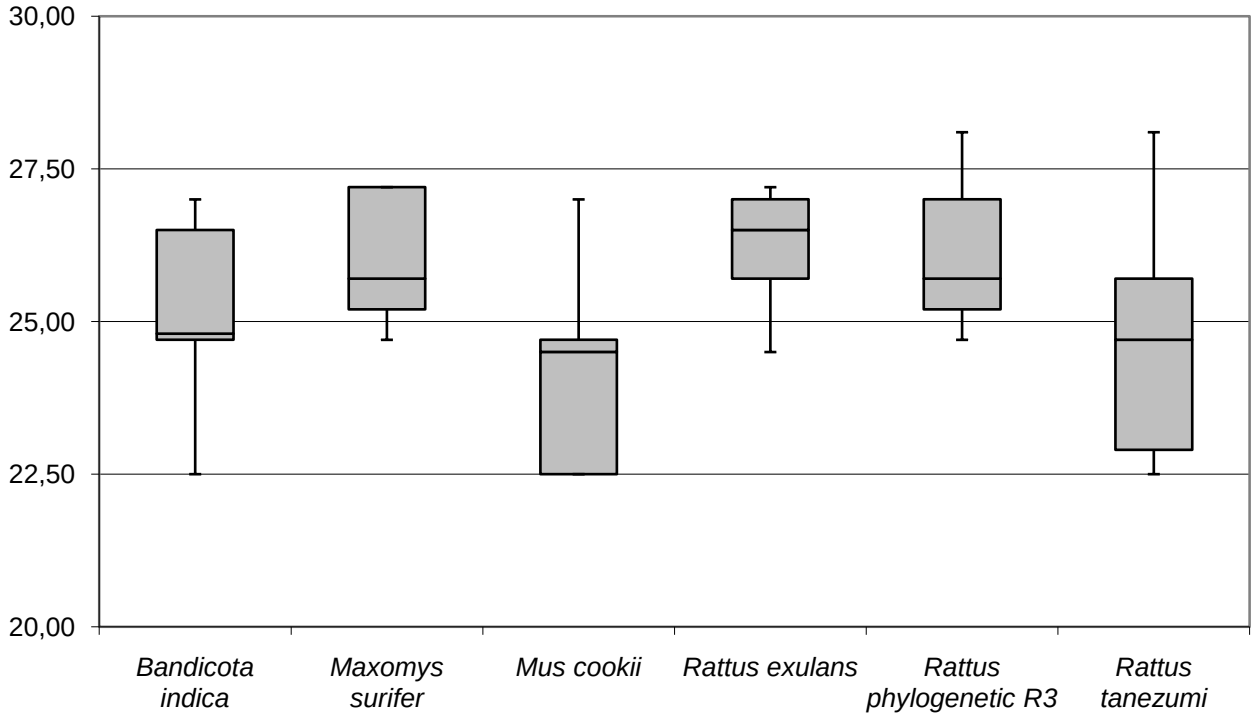
Species	Number	Average elevation	Minimum elevation	Maximum elevation	Range
Bandicota indica	97	254,7	113	558	445
Bandicota savilei	49	171,1	115	379	264
Berylmys berdmorei	27	221,8	8	358	350
Berylmys bowersi	15	391,9	253	587	334
Maxomys surifer	86	133,0	11	379	368
Mus caroli	91	298,5	163	594	431
Mus cervicolor	126	220,4	154	358	204
Mus cookii	125	402,3	206	878	672
Niviventer fulvescens	63	276,6	20	379	359
Rattus argentiventer	37	30,8	2	190	188
Rattus exulans	494	159,8	2	379	377
Rattus losea	85	288,6	162	379	217
Rattus phylogenetic R3	133	76,4	1	316	315
Rattus tanezumi	181	329,2	4	587	583
Suncus murinus	42	5,6	2	32	30
Total	**1651**	**217,4**	**1**	**878**	**877**

Results:

Ecological ranges

- Based on global data (DEM, climate):

Example: Range of average temperatures per species



→ Ranges are depending on the study sites

→ Further samplings will enhance the knowledge of each species' ecological ranges.

Results:

Distances to classes

• Selection of 6 species and samples with an accurate knowledge of the sampling location:

Site	*Bandicota indica*	*Maxomys surifer*	*Mus cookii*	*Rattus exulans*	*Rattus phylogenetic R3*	*Rattus tanezumi*	Total
Lao PDR - Luang Prabang	-	-	37	-	-	1	**38**
Thailand - Nan	5	-	20	1	-	9	**35**
Thailand - Loei	-	4	22	2	1	2	**31**
Lao PDR - Champasak	-	-	-	17	3	2	**22**
Thailand - Buriram	-	-	1	58	22	3	**84**
Cambodia - Mondolkiri	1	29		38	26	4	**98**
Cambodia - Preah Sihanouk	-	37	-	59	53	1	**150**
Total	**6**	**70**	**80**	**175**	**105**	**22**	**458**

Results:

Distances to classes

- Selection of 6 species:

Bandicota indica

Maxomys surifer

Mus cookii

Rattus exulans

Rattus R3

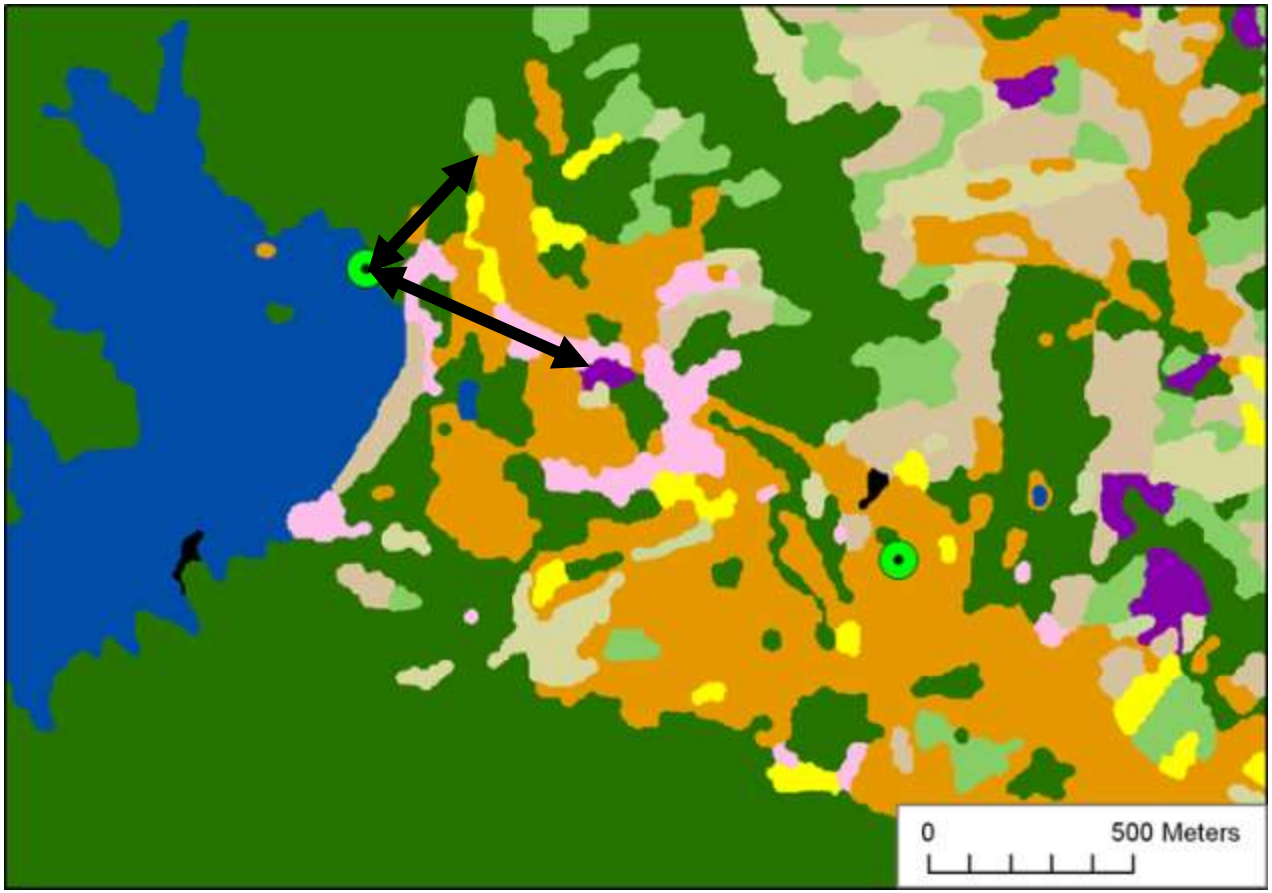
Rattus tanezumi

Photos: Herbreteau V.

Results:

Distances to classes

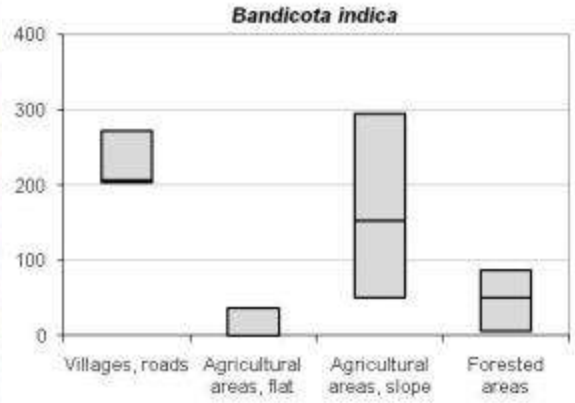
- Shortest distance to each class:

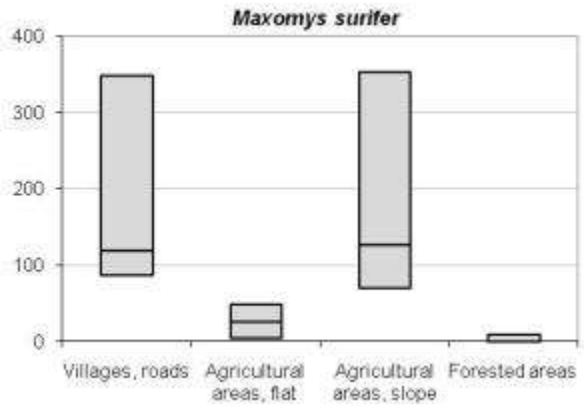


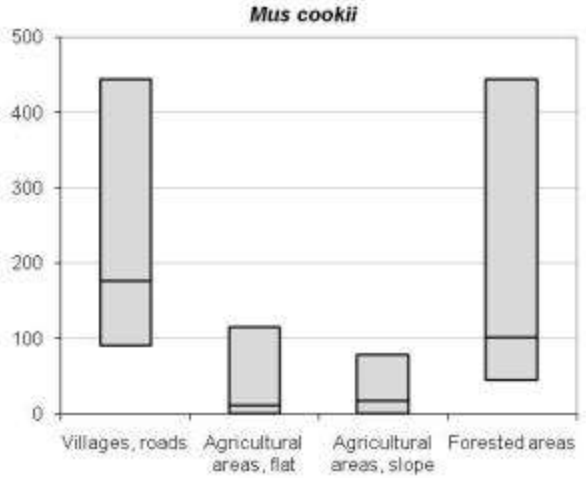
Results:

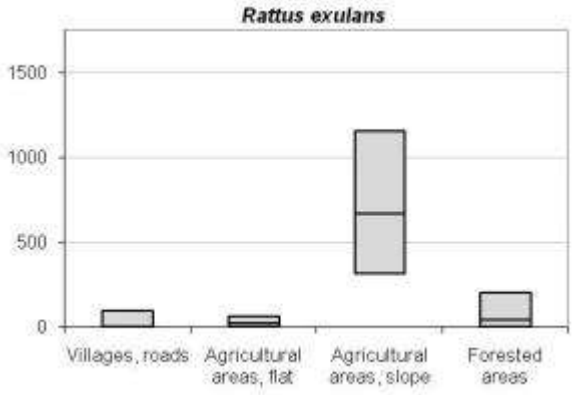
Distances to classes

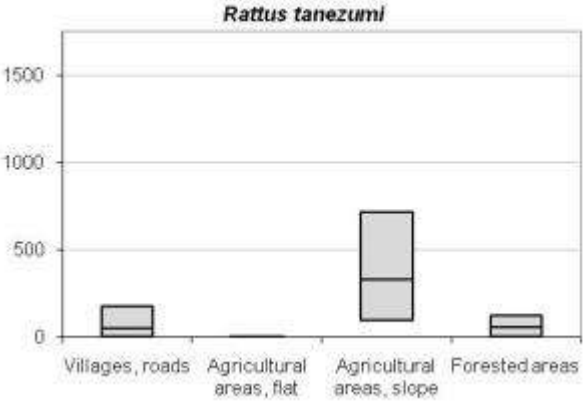
- Shortest distance to each class:

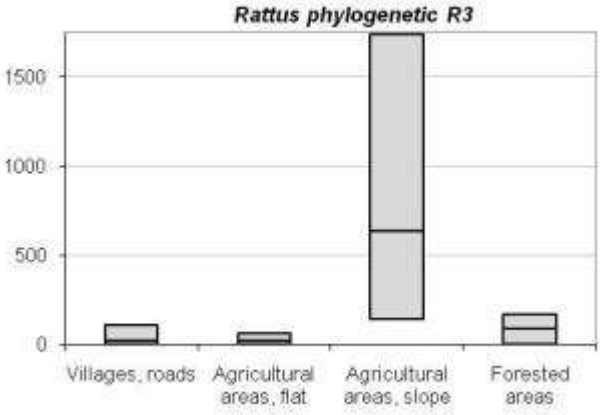








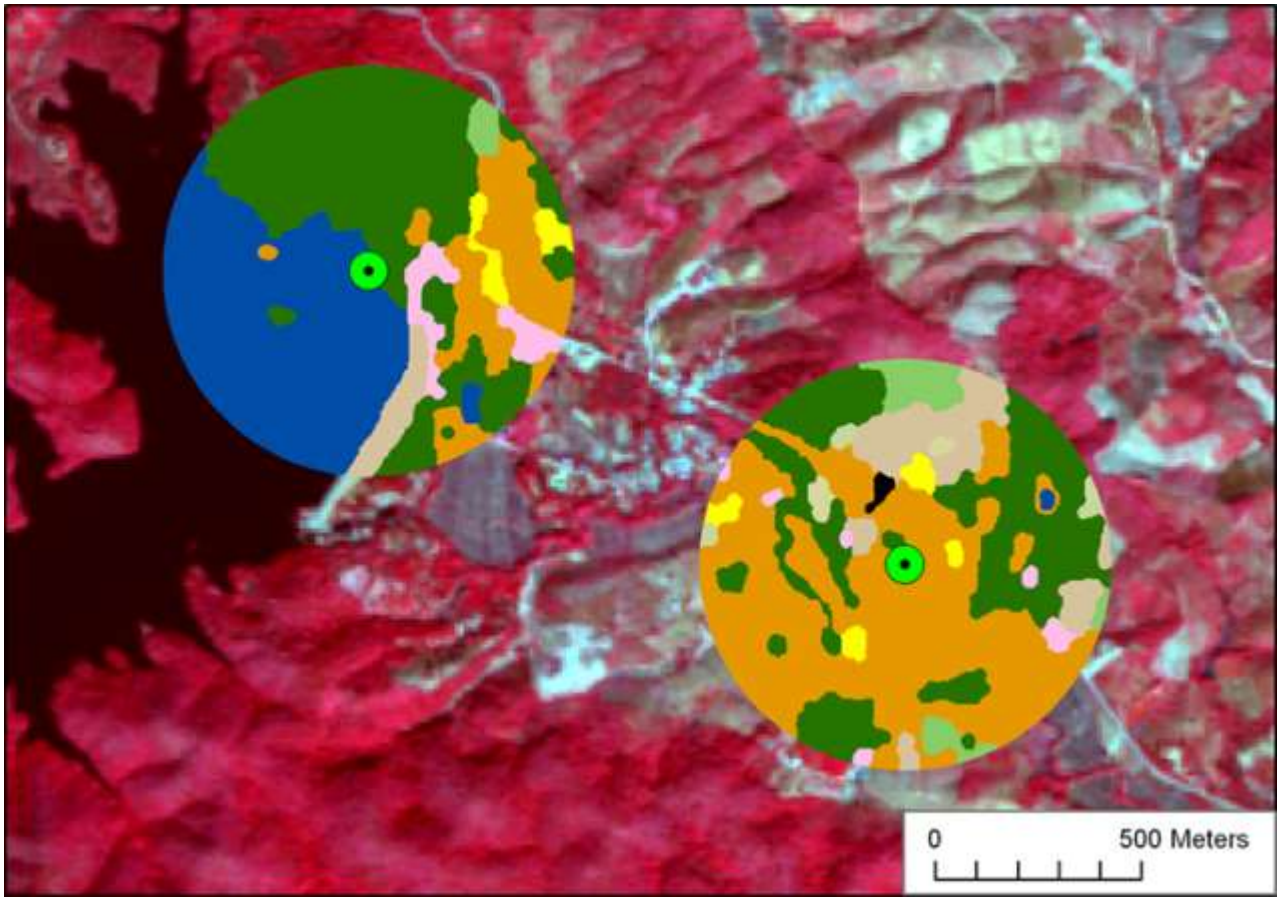




Results:

Landscape metrics

- Buffer analysis



→ Calculation of the proportion of each class around sampling locations

→ Calculation of landscape metrics: PD, ED, SHDI, SHEI, SIDI.

Results:

Disriminant analysis

- Discriminant analysis (forward stepwise):
  - 19 available variables:

    - Longitude, latitude,

    - Elevation,

    - Proportion of 5 classes inside the buffer: Water, Agricultural area-flat, Agricultural area-steep, Roads-villages, Forested areas,

    - Landscape metrics: PD, ED, SHDI, SHEI, SIDI,

    - 6 climatic variables: Rainfall of the driest month, of the wettest month, Annual rainfall, Minimum temperature of the coldest month, Maximum temperature of the warmest month, Average temperature.

Results:

Disriminant analysis

- Discriminant analysis (forward stepwise):
  - 19 available variables.
  - The best model can predict 74,5% of the 5 species:

	Wilks' - Lambda	Partial - Lambda	p-level
Latitude	0,165954	0,702933	0,000000
Elevation	0,138322	0,843352	0,000000
Annual rainfall	0,137007	0,851449	0,000000
Prop. Forested areas	0,129674	0,899598	0,000010
Rainfall wettest month	0,132332	0,881530	0,000001
Average temp.	0,123372	0,945547	0,004464
Shannon Div. Index	0,125543	0,929200	0,000541
Edge density	0,122778	0,950122	0,007912
Prop. Artificial areas	0,120147	0,970927	0,092838

Results:

Disriminant analysis

- Discriminant analysis (forward stepwise):
  - 19 available variables.
  - The best model can predict 74,5% of the 5 species:

Species	% of correct prediction
Bandicota indica	63,64
Maxomys surifer	71,83
Mus cookii	89,19
Rattus R3	79,61
Rattus tanezumi	13,04
Total	**74,11**

Discussion

How to extrapolate local results?

• High resolution data (i.e. land cover classification) not available over the distribution of the species.

→ Possibility to calculate similar landscape metrics with GlobCover

→ Need to compare results using SPOT vs GlobCover

→ Need to simplify models, deal with autocorrelated data

Discussion

Limitations of the use of high resolution data

- A limited approach in time:
  - Animal samples / land cover are described at a given date
  - Environmental changes can be very fast:

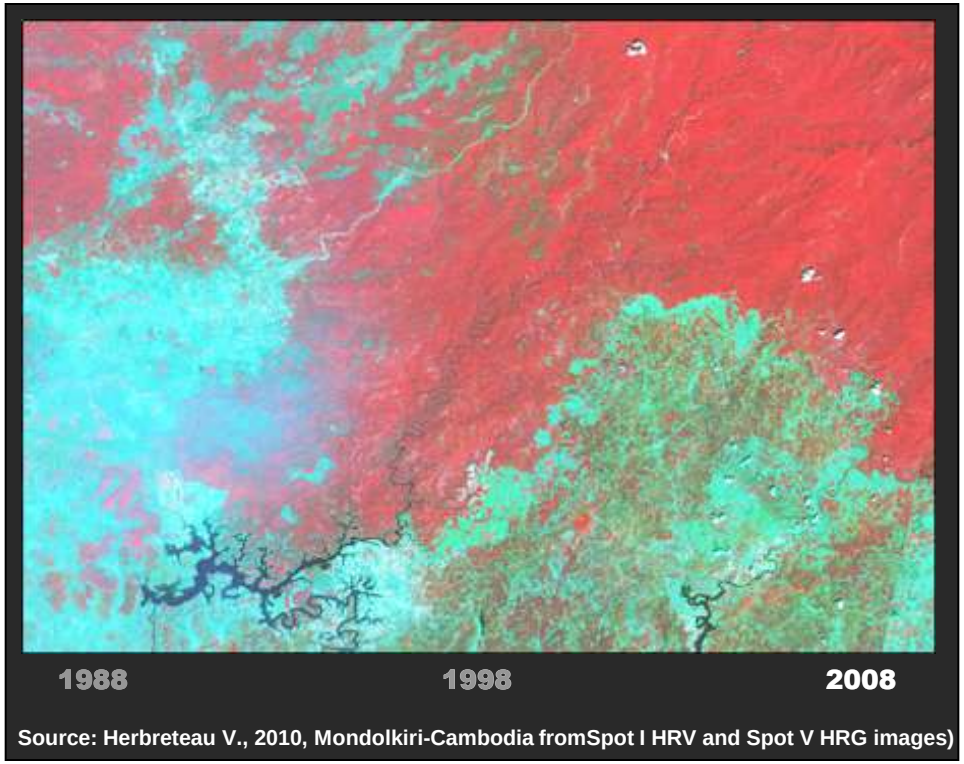
Discussion

Limitations of the use of high resolution data

- A limited approach in time:
  - Animal samples / land cover are described at a given date
  - Environmental changes can be very fast:

→ need to process images regularly,

→ difficulty to compare images at different resolutions.



Source: Herbreteau V., 2010, Mondolkiri-Cambodia fromSpot I HRV and Spot V HRG images)

Discussion

Limitations of the use of high resolution data

- A limited approach in time:
  - Animal samples / land cover are described at a given date
  - Environmental changes can be very fast:

- Difficulties to integrate the human activities impacting land use and rodents dynamics:
  Agricultural shifts, hunting, introduction of species, etc.

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